Draft Macroinvertebrate Sampling Report Devils Lake Study

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TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

Section **Page**

LIST OF TABLES

Table

LIST OF FIGURES

Figure

LIST OF APPENDICES

Appendix

LIST OF ACRONYMS AND ABBREVIATIONS

µm	micrometer
µS/cm	microSiemens per centimeter
cfs	cubic feet per second
cm	centimeter(s)
DO	dissolved oxygen
DWQ	Division of Water Quality
EMAP	Environmental Assessment and Monitoring
EPT	Ephemeropter, Plecoptera, and Trichoptera
ETOH	ethanol
GPS	Global Positioning System
m	meter(s)
m/s	meters per second
NAWQA	National Water-Quality Assessment Program
NDDH	North Dakota Department of Health
NDGFD	North Dakota Game and Fish Department
NTU	Nephelometric Turbidity Units
RBP III	Rapid Bioassessment Protocol III
SCUBA	self-contained underwater breathing apparatus
SRIAP	Sheyenne River Invertebrate Assessment Project
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VCSU	Valley City State University

EXECUTIVE SUMMARY

PURPOSE

The purpose of the macroinvertebrate sampling project was to develop and implement procedures to collect and identify the macroinvertebrate fauna of the Sheyenne River and Devils Lake. This project incorporated biomonitoring to examine the health of the aquatic environment. Biomonitoring is the process of cataloging of what organisms live in a particular habitat and then, based on knowledge of the conditions those organisms tolerate, determining the condition of that habitat. Biomonitoring of aquatic invertebrates is recognized as an important tool for documenting baseline conditions and monitoring possible changes in the health of an aquatic system. This study is an integral part of the planning and Environmental Impact Statement (EIS) process being conducted on the proposed Devils Lake Outlet.

This project accomplished two main objectives. First, it documented the current baseline macroinvertebrate fauna of the Sheyenne River and Devils Lake - important for addressing the issues of potential changes in macroinvertebrate assemblages or the introduction of foreign species caused by the operation of an outlet. Second, it established a protocol for continued evaluation of the Sheyenne River and Devils Lake (i.e., biomonitoring). These objectives were accomplished using a combination of multihabitat and single-habitat sampling (as described in the Methodology section below).

METHODOLOGY

As part of this project, a manual was developed specifying protocols for macroinvertebrate collection, identification, and handling. The protocol manual also included equipment lists and identified sampling sites. An overview of the protocols, along with the data collected as part of this project and the analysis of that data, are included in this document.

Twenty-eight invertebrate sampling sites were established for this study and potential future monitoring activities. Eighteen of the sites are located in the Sheyenne River; twelve of these are sites where the U.S. Army Corps of Engineers (USACE) had previously collected aquatic habitat data. Of the ten remaining sites, seven are located within Devils Lake (two in West Bay and one each in Main Bay, East Bay, East Devils Lake, East Stump Lake, and West Stump Lake) and three are located in Lake Ashtabula. The sites were sampled three times in 2001: once in the early spring soon after flooding (May), once in mid-July, and once in late summer/fall (September).

Two procedures were used for macroinvertebrate river sampling. One method was based on the U.S. Environmantal Protection Agency (USEPA) publication *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition*. (Barbour *et al.,* 1999). This type of sampling is called multihabitat sampling because an attempt is made to sample all pertinent habitats within a reach. Sampling areas within the reach are unique for each site. The second procedure was a modified version of the USEPA *Environmental Monitoring and Assessment Program* (EMAP) non-wadeable protocol. This is called single-habitat sampling because samples are collected from a predetermined area of the reach that is similar for all sites within the reach.

There is currently a debate as to which type of sampling is best suited for biomonitoring. It is argued that single-habitat sampling is a faster, more cost-efficient method of detecting changes in the biotic composition of a river, and that since similar habitat is sampled at each site it gives more comparable

results. However, single-habitat sampling does not document the entire macroinvertebrate community of a river. A multihabitat technique, similar to the USEPA's rapid biological sampling protocols, is thought to get as complete a documentation of the macroinvertebrate biota as possible. This was an important consideration. It was thought that if the two methods give similar results, the single habitat sampling could be used later as a quick means of assessing whether change has occured in the biota of the system.

Because of the variety of habitats encountered, both wadeable and nonwadeable collecting was necessary. The sampling protocol was designed to be easily repeatable for the purpose of future monitoring of the effects of an outlet on the macroinvertebrates of Devils Lake and the Sheyenne River.

The scope of work included the collection of additional field data. At each site some basic water parameters were recorded at the time of macroinvertebrate sampling. A Hydrolab was used to measure water temperature, pH, turbidity, conductivity, and dissolved oxygen. Physical parameters such as flow, stream width, water depth, and general habitat were also recorded.

After samples were collected they were sorted and prepared for identification. Samples were identified to the lowest taxon possible. There is considerable debate as to the level of identification necessary for biomonitoring. While several studies seem to show that family level identification is sufficient, as many samples as possible should be identified to the genus or species level. This is especially important for identifying the overall macroinvertebrate fauna of the system. Voucher specimens for this project have been incorporated into an existing reference collection of invertebrates maintained at Dr. DeLorme's macroinvertebrate lab at Valley City State University (VCSU) in Valley City, North Dakota.

A mussel survey was conducted at wadeable sites. Mussel species were collected at several sites and up to five specimens of each species were kept as voucher specimens. All others were returned alive to the streambed from which they were taken.

This document also reviews and summarizes existing information on macroinvertebrate surveys in the Sheyenne River, including published and unpublished information on previously collected field data from Federal and State agencies, and from educational institutions, such as colleges and universities (Appendix A). This information is summarized in conjunction with the field data collected as part of this project.

One of the goals of this project was to perform statistical analysis of the data, but the time available for data collection and interpretation precluded extensive statistical evaluation. Although some data analysis is presented in this document, additional data analysis may be necessary in the future, depending upon the end use of the results. Further, the lack of historical data on North Dakota macroinvertebrates limited the interpretation of the current work. The North Dakota Department of Health (NDDH), which has been sampling macroinvertebrates since 1995, is currently devising a Biotic Index for macroinvertebrates in North Dakota rivers. Unfortunately, this Index is not yet available, but will be useful in the future.

RECOMMENDATIONS

This project work has generated three general recommendations for future work:

1. If an outlet is built, macroinvertebrate sampling should be carried out every summer until the outlet is complete, and every summer after that until sampling shows a stabilization of biota.

One year of sampling does not provide adequate baseline information. The more data generated before construction of the outlet, the better the ability to measure the effects of the outlet on river biota will be.

2. Future sampling should focus on multihabitat protocols. Experience on this project indicated that single-habitat sampling did not save much time or energy and was not adequate in all seasonal situations.

3. A separate, thorough mussel survey should be completed on the Sheyenne River. The survey for this project did not adequately document the mussel biota of the river. If an outlet is built, mussels should also be surveyed on a yearly basis.

SUBMITTALS

The following submittals are provided as part of this deliverable:

- Final Project Report (Text and Appendices A-C).
- Access database with all project data (provided under separate cover).
- Photographs for all sites during all sampling periods (Appendix D).
- Maps for locating sites (Appendix E).

1.0 INTRODUCTION

1.1 BACKGROUND

The Sheyenne River is located entirely within the boundaries of the State of North Dakota. At approximately its midway point, Baldhill Dam forms a long reservoir called Lake Ashtabula. The river eventually flows into the Red River, which flows north into Canada and is part of the Hudson Bay drainage system. The USACE is evaluating the potential impact of discharging Devils Lake into the Sheyenne River as a possible means of lowering the water level in nearby Devils Lake. Devils Lake, part of a closed drainage basin, is located in north-central North Dakota and is experiencing extreme flooding problems. This particular study documents the macroinvertebrate biota of the Sheyenne and establishes baseline data for long-term macroinvertebrate biomonitoring of the Sheyenne.

1.2 BIOMONITORING

Biomonitoring is the process of cataloging the organisms that live in a particular habitat and then, from the knowledge of what conditions those organisms tolerate, determining the health of that habitat. Macroinvertebrate biomonitoring is recognized as an important tool in documenting the health of an aquatic environment and any changes that may occur. It can provide information about the bioaccumulation of toxins over time, the quality of aquatic habitats, and the sporadic discharges that standard chemical monitoring would miss. Long-term monitoring can also be instrumental in detecting biotic disturbances. It is critically important to establish baseline data for a watershed. Any future monitoring will be compared to this baseline data, and if degradation occurs, there will be a reference for restoration.

This project established a comprehensive sampling program that generated baseline data for macroinvertebrate biomonitoring. It provided not only macroinvertebrate data, but also data on water quality, water flow, and general habitat characterization. This study is meant to serve as a beginning of a longer-term sampling regime if there is to be future monitoring. It is not meant to be an end point; one year of sampling does not constitute an adequate baseline.

1.3 ACKNOWLEDGEMENTS

Funds for this study were provided by the USACE, St. Paul District. Mr. Robert Anfang was the USACE's technical manager. Ms. Leslie Knapp (Earth Tech, Inc.) managed the project. Dr. Andre DeLorme of VCSU, was the primary author of this document and supervised all sampling efforts. He was assisted by Ms. Knapp, Mr. Jeremiah Menk, Mr. Karl Primdahl, and Mr. John Wiater of Earth Tech, Inc. Louis Wieland, a lab technician in the VCSU macroinvertebrate lab, was instrumental in putting together many of the charts and figures in this document. The NDDH, Division of Water Quality (DWQ) provided data for two years of sampling for this report. Dr. Malcolm Butler provided important input on the lake sampling protocol.

2.0 OVERVIEW OF PAST STUDIES

Very little macroinvertebrate sampling has been conducted in North Dakota in general, or in the Sheyenne in particular. A review of the literature reveals that before 1995 no systematic macroinvertebrate sampling was being done in a biomonitoring context. There are several general articles and publications on the distribution of certain groups within the state. Bick (1977) published "An Annotated List of the Odonata of the Dakotas." This paper lists the known species of dragonflies and damselflies for North and South Dakota, with general statements of abundance and location, but no quantitative data are included. A similar review of the Trichoptera (caddisflies) of North Dakota was provided by Harris *et al.*, (1980). Once again, this document simply lists known species in the state. It describes the distributions of these species by dividing the state into six areas and listing the species that occur in each area. Jacobson (1969) published a set of keys, descriptions, and distributions of the aquatic Hemiptera of North Dakota. Gordon and Post (1965) published a similar document for the water beetles of North Dakota. All of these works describe only general distribution patterns; and none is specific to the Sheyenne. While the literature was useful in verifying possible species identifications, it did not provide any historical biomonitoring information.

2.1 RIVER MACROINVERTEBRATE STUDIES

Since 1995, several government agencies and researchers have begun macroinvertebrate sampling in the Red River Basin and Sheyenne River watershed. Some of this unpublished data was available for review (see Appendix B and the descriptions below).

2.1.1 Sheyenne River Invertebrate Assessment Project (SRIAP)

In the fall of 1997, Dr. DeLorme began the Sheyenne River Invertebrate Assessment Project (SRIAP). Invertebrate samples were collected in the river from late summer through fall, with most sites being sampled at least twice. The sites were located near the Valley City area, approximately 12 miles below Baldhill Dam. The first year a qualitative approach was used to examine what taxa were present. In subsequent sampling years, taxa were identified with a protocol adopted by the NDDH [and based on the USEPA Rapid Bioassessment Protocol (RBP) III]. Sample collection was identical to the multihabitat sampling of this project. The protocols differed with respect to selecting macroinvertebrates from the sample, however. In SRIAP, sample selection was done on site. For the current study, samples were brought back to the lab and selected under 10× magnification. This difference in protocols would be expected to result in a difference in the number of small taxa, such as chironomid larvae. This is apparent when comparing invertebrate data for Millers Crossing, which was sampled in the same reach for both the SRIAP and this project. The comparison of taxa lists of Site AC13 from this project with field number sites 98005 and 99001 from the SRIAP study shows a high number of chironomids in the current project, while very few were recorded in the SRIAP study. However, the numbers of the common taxa other than chironomids are similar.

Several other SRIAP sites are in close proximity to both NDDH sites and sites sampled during this project. Included in Appendix B are the SRIAP taxa lists for the three years sampling was done.

2.1.2 The North Dakota Department of Health

The NDDH DWQ began a statewide macroinvertebrate sampling program in the summer of 1995. The DWQ is using the USEPA RPB III sampling protocols, which are similar to our multihabitat sampling protocol. In the summer of 1995 the NDDH sampled the Red River Valley area, including the Sheyenne River. Twenty-four sites were sampled on the Sheyenne River in 1995. In 1996 the NDDH returned and resampled one site three times and seven other sites once. In subsequent years the NDDH has been sampling other rivers in North Dakota, so they have only these two years data on the Sheyenne. Taxa lists for both of these sites are found in Appendix B.

Comparison of the SRIAP data and our current sampling efforts with the NDDH data shows a much lower taxa count in the NDDH work. This is especially true for the 1995 data, which have taxa richness numbers often below ten and as low as two in some sites. These are very low numbers. It is interesting to note that comparison of 1995 NDDH data with 1996 NDDH data does show almost a doubling of taxa richness scores. It is not known if this variation is related to the first year sampling efforts or to an actual variation in the biota in 1995.

The NDDH plans to return to the Sheyenne and Red River Basin this summer for macroinvertebrate work (Mike Ell, NDDH, personnel communication). In addition, in the fall of 2001 they sampled 13 sites for macroinvertebrates on the Sheyenne as part of a larger nutrient study. This sampling followed the USEPA's *Environmental Monitoring and Assessment Program* (EMAP) protocol that is similar to this project's single-habitat sampling protocol. The NDDH data will become available at the end of the two-year project.

2.1.3 USEPA Environmental Monitoring and Assessment Program

In the summer of 2000, USEPA initiated the EMAP in North Dakota. This is a four-year study, administered through the NDDH, which samples randomly selected stream and river sites for a wide variety of water quality parameters, including macroinvertebrates. In the summer of 2001, the EMAP crews were scheduled to survey several sites on the Sheyenne River however, since their approach is to sample only wadeable streams, the high-water conditions this summer limited their sampling. The identification and cataloging of macroinvertebrates collected at sampled sites were not available at the time this document was prepared.

2.1.4 U.S. Geological Survey National Water-Quality Assessment Program

In the mid-1990s, the United States Geological Survey (USGS) examined the Red River Basin as part of the National Water Quality Assessment (NAWQA) Program. This project included macroinvertebrate sampling on the entire Red River Basin, and several sites on the Sheyenne River were sampled. This project was discontinued in September of 2001 and work on the macroinvertebrate component has not been published and was unavailable. However, it is possible that the USGS will release its samples to Dr. DeLorme to be included in the Macroinvertebrate Laboratory's collection of North Dakota Aquatic Invertebrates. Efforts are being made to obtain any information they may have on the Sheyenne at this time.

2.2 LAKE MACROINVERTEBRATE AND ZOOPLANKTON STUDIES

As with the rivers of North Dakota, there have not been many studies for macroinvertebrates in either Lake Ashtabula or Devils Lake. Peterka did most of the available studies on both lakes (Peterka 1986; Peterka 1972; Peterka and Knutson 1970; Peterka and Reid 1968). Although his work did include macroinvertebrates, much of it involved zooplankton. In Lake Ashtabula he found that chironomids made up the largest percentage of macroinvertebrates sampled, about 56 percent, with oligochaetes making up about 22 percent. This project's data from Site 19, which is very close to the sampling site Peterka used, shows chironomids were by far the most common macroinvertebrates. Oligochaetes, however, were not as common (see Appendix B). It should be noted that in other sites in Lake Ashtabula large numbers of oligochaetes were found. In examining zooplankton, Peterka found large numbers of Daphnia and lesser amounts of copepods. This is consistent with the findings of the current study.

2.3 MUSSEL SURVEYS

Several major surveys for mussels have been conducted on the Sheyenne River. Cvancara (1983) carried out extensive sampling of mussels in North Dakota rivers during the 1960s and 1970s. During this work he surveyed 25 different sites on the Sheyenne River. Cvancara's work was published as "Aquatic Mollusks of North Dakota" and it is still regarded as the most complete work done on North Dakota mussels. He recorded at least 10 different species of unionoid mussels present in the Sheyenne River.

In the early 1990s, the North Dakota Game and Fish Department (NDGFD) conducted mussel surveys on the Sheyenne River and parts of the Red River (Jensen *et al.* 2001). They sampled 22 sites on the Sheyenne River and eight on the Red River. Twelve different species were recorded in the Sheyenne River, with *Amblema plicata, Fusconaia flava, Pyganodon grandis,* and *Lampsilis silquoidea* being the most common mussels. Higher densities and diversity of mussels were seen in the reaches of the lower Sheyenne River (i.e., downstream of Lake Ashtabula) as compared to the upper Sheyenne River (upstream from Lake Ashtabula). The NDGFD also noted that, compared to Cvancara's work, most members of the Anodontinae and Lampsilinae subfamilies appeared to have declined since the early 1970s.

3.0 SUMMER 2001 RIVER MACROINVERTEBRATE SAMPLING

The macroinvertebrate sampling for this project included both single-habitat and multihabitat sampling. In addition to the macroinvertebrates, some basic water parameters were also sampled at each site. A Hydrolab was used to measure water temperature, pH, turbidity, conductivity, and dissolved oxygen (DO). Physical parameters such as flow, stream width, water depth, and general habitat were also recorded.

3.1 SITES SAMPLED

There are a total of 18 sites on the Sheyenne River (Table 1). Twelve sites were designated by the USACE. The other six sites, chosen by Dr. Andre DeLorme, were selected because they had already been sampled by either Dr. DeLorme's lab or by the NDDH. Sites were numbered from 01 to 18, with Site 01 being the farthest upstream site and Site 18 being the farthest downstream site. Sites 01 through 10 are located upstream of Lake Ashtabula and Sites 11 through 18 are downstream from Lake Ashtabula. The sites were sampled three times, once in the early spring soon after flooding (middle to late May), once in mid-July, and once in late summer/fall (mid-September).

U.S. Geological Survey topographic maps were used to find the approximate location of the sites. Sites from the 12 reaches supplied by the USACE had been previously marked with a field marker. Maps of the sampling area were supplied by Earth Tech, Inc. The field markers were difficult to find, so the X site was established using the maps. The X is defined as the middle of the sampling reach. On designation of the X site, a Geographic Positioning System (GPS) reading was taken and recorded on the River Field Data sheet as the site of the X cross-section. A Garmin GPS III Plus with a non-differential accuracy of 15 meters (m) was used. At the six sites previously established by the NDDH, USGS maps were used to find the approximate area and then the GPS was used to find the coordinates. At all sites, pictures were taken of the X cross-section with a digital camera. In addition, at least one photo downstream of the X and one photo upstream of the X were taken. These pictures have been compiled for all three sampling sessions and are located on the CD-ROM accompanying this report. Also included are the pictures for the July sampling period (see Appendix D).

After location and verification of the X site, a 100 m reach was established by measuring 50 m downstream and 50 m upstream from the X site. For the single-habitat procedure, the reach was marked every 10 m with flags. Red flags were used to mark the upstream limit, downstream limit, and X site of the reach, and yellow flags were used to mark the intermediate cross-sections. All sites were marked on a USGS topographic map (See Appendix E).

The location of one of the NDDH sites, Site 02, had to be moved because it was inaccessible. The new site is located approximately one mile upstream of the original site.

3.2. DISCHARGE MEASUREMENTS

3.2.1 Protocol Overview

The velocity-area procedure, as outlined in *Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams* (EPA document 620-R-94-004F), was used to determine stream discharge. This procedure is based on the concept of measuring the mean velocity and flow

cross-sectional area of many increments across a channel. These measurements are then compiled to give an overall discharge value. As per the protocol outlined in the manual, an 0.6 depth reading was used for velocity measurements. The protocol was as follows:

Flow measurement was taken at the X cross-section. Consistent with the guidance, this cross-section of the stream channel was selected to have most of the following qualities:

- No confluences (tributaries entering the channel) within 50 m upstream or downstream of the X site.
- Segment of stream above and below cross-section was straight.
- Depths were mostly greater than 15 cm, and velocities were mostly greater than 0.15 meters/second (m/s). Discharge was not measured in a pool.
- "U" shaped, with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.
- Flow was relatively uniform, with no eddies, backwaters, or excessive turbulence.

The surveyor's rod was laid (or a steel or nonstretchable fiberglass meter tape was pulled) across the stream perpendicular to its flow with the "zero" end of the rod or tape on the left bank, as viewed when looking downstream. The tape was left tightly suspended across the stream, approximately one foot above water level.

After velo meter was attached to the calibrated wading rod, it was checked to ensure it was functioning properly and that the correct calibration value was displayed. The calibration of the velocity meter and probe was checked as directed in the meter's operating manual.

The total wetted stream width was divided into 15 to 20 equal-sized intervals. The interval width was mined by dividing the width by 20 and rounding up to a convenient number. Intervals were not less than 10 centimeters (cm) wide; even if this resulted in fewer than 15 intervals. The first interval was located at the left margin of the stream (left when looking downstream), and the last interval was located at the right margin of the stream (right when looking downstream).

> Standing downstream of the rod or tape and to the side of the midpoint of the first interval (closest to the left bank if looking downstream), the wading rod was placed in the stream at the midpoint of the interval and the probe propeller was adjusted so that it was at the water surface. The distance from the left bank (in cm) and the depth indicated on the wading rod (in cm) were recorded on the Discharge Measurement Table on the back of the River Field Data Sheet. (Note: For the first interval, distance equaled 0 cm, and in many cases depth may also have equaled 0 cm. For the last interval, distance equalled the wetted width (in cm) and depth may again also have equalled 0 cm.

Standing downstream of the probe or propeller to avoid disrupting the stream flow, the position of the probe on the wading rod was adjusted so it was at 0.6 of the measured depth below the surface of the water. The probe was positioned upstream at a right angle to the cross-section, even if local flow eddies

hit at oblique angles to the cross-section. After waiting 20 seconds to allow the meter to equilibrate, the velocity was measured and the value was recorded on the Discharge Measurement Table.

After moving to the midpoint of the next interval, Steps 6 through 8 were repeated. The process was continued until depth and velocity measurements had been recorded for all intervals. At the last interval (right margin), a "Z" flag was recorded in the note section of the Discharge Measurement Table to denote the last interval sampled.

For non-wadeable sites, a bridge was located that crossed the river in the near vicinity of the sampling site. GPS measurements were taken from the center of the bridge and recorded on the Discharge Measurement Data Sheet. A bridge-board apparatus was used to suspend the flow meter and the method described above was used for determining flow.

3.2.2 Discharge Results

A summary of the discharge measurements is found in Figure 1. Discharge measurements could not be recorded for some sites during each of the sampling periods.

Discharge measurements show the expected increased flows with progression downstream. They also show the high-water conditions that were present in both May and July as compared to September. Readings for several sites were compared with readings from USGS gauging stations. Although none of the current study's sites are located at a USGS gauging station, several are located within two miles of a gauging station. The site closest to a gauging station is Site 11, located below Baldhill Dam. The flow readings for this site are comparable to the readings at the nearby USGS site. At Site 11, the reading on May 16 was a flow of 551 cubic feet per second (cfs) and the gauging station read 604 cfs; on July 21 the Site 11flow was 228 cfs and the gauging station read 217 cfs; and on September 15 Site 11 recorded a flow of 58 cfs and the gauging station recorded 52 cfs.

3.3 WATER QUALITY MEASUREMENTS

3.3.1 Protocol overview

A Hydrolab was used to measure five components of water quality: pH, temperature, specific conductivity, turbidity, and DO content. A barometer was used each day to calibrate the Hydrolab for DO measurements. The Hydrolab measurements were made in the thalweg, defined as the deepest part of the stream channel, of the X cross-section. The probe was placed at 0.6 of the depth, measuring from the surface. Measurements were taken at all sites. The only problem encountered was that at the very beginning of the project the standards necessary to set the turbidity meter portion of the Hydrolab had not been received. A Secchi disk was used to measure turbidity at the first few sites in May until the turbidity meter could be standardized.

The Hydrolab was calibrated before each sampling period and every few days during sampling periods using premixed calibration standards.

3.3.2 Summary of Results

Graphs and data for the water quality measurements at each site are provided in Figures 2 through 6. Measurements are all within expected ranges with the exception of the turbidity reading for Site 05 in the third sampling period. The reason for this uncharacteristically high measurement is not known. Overall, our measurements show the Sheyenne to be a slightly alkaline river, with fairly high turbidity and specific conductivities. As with much of the data from this study, the turbidity and specific conductance data will become more significant with additional years of study. The ability to track changes in these water quality measurements with changes in flow, habitat structure, and biota composition will be important.

3.4 HABITAT MEASUREMENTS

3.4.1 Protocol Overview

Since the USACE has already performed habitat assessments on 12 of the river reaches (Earth Tech, Inc. 1998), habitat documentation as part of this project was meant to be only a quick assessment to document any gross changes in the reach. In this assessment, the group photographed the reach and measured the width and depth of the stream. The channel width was measured at the X cross-section and both the upstream and downstream limits of the 100 m reach. Depths were also taken at these three locations. Depths were recorded at ¼, ½, and ¾ of the channel width. In addition, a depth at the thalweg of these three cross-sections was recorded. The ¼ depth was designated to be on the left hand side of the channel, as viewed when looking downstream. A total of 9 to 12 depth measurements were taken at each site, depending on the location of the thalweg. A summary of the width and depth measurements at the midpoint of the X site for all sites during each sampling session are found in Figures 7 and 8. Complete measurements for all sites can be found in the database on the CD-ROM accompanying this report.

A digital camera was used to take photographs of each site for both site verification and habitat documentation. These photos have been compiled for all sites for all three sampling sessions. The digital files for these photos are located on the CD-ROM accompanying this report. The photographs for the July sampling are included in this document in Appendix D.

The final part of the habitat assessment involved rating the following parameters for low-gradient streams, as outlined in Rapid *Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish* (Barbour *et al*. 1999): width of riparian zone; vegetative protection; channel flow status; and pool substrate characterization. Since these scores are subjective, one person was designanted to do the scoring for all sites during all three sampling periods. This part of the habitat assessment was done after all other sampling had been completed. Having sampled the various microhabitats and walked the reach helped ensure a more accurate assessment.

3.4.2 Summary of Results

Data and graphs for width at the X and depth at the middle of the X are located in Appendix B. A complete list of all depth and width measurements can be found in the Access database on the CD-ROM accompanying this document. Habitat measurements for width of riparian zone, vegetative protection, channel flow status, and pool substrate characterization are located in Table 2.

3.5 MACROINVERTEBRATE SAMPLING OF THE SHEYENNE RIVER

3.5.1 Protocol Overview

Two methods of sampling with D-frame nets are currently widely used. The first, outlined in Rapid *Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish* (Barbour *et al*. 1999), is called the multihabitat method. The multihabitat protocol provides for the sampling of all the habitat types found within a reach using a kick or jab technique with the D-frame net. A total of 20 jabs or kicks are taken over the length of the reach; a single *jab* consists of forcefully thrusting the net into a productive habitat for a linear distance of 0.5 m. A *kick* is a stationary sampling accomplished by positioning the net and disturbing the substrate for a distance of 0.5 m upstream of the net. This can be done in two ways – either standing on the upstream side of the net and shuffling feet upstream for 0.5 meters so that disturbed organisms are taken into the net by the current; or using a stick or other implement to disturb the bottom 0.5 meters upstream of the net. Different types of habitat are to be sampled in approximate proportion to their representation of surface area of the total macroinvertebrate habitat in the reach. For example, if riffles comprise 50 percent of the habitat in the 100 m reach and snags comprise 20 percent, then 10 jabs should be taken in riffle areas and four jabs should be take in snag material. The remainder of the jabs (six) would be taken in any remaining habitat type. Habitat types contributing less than 5 percent of the stable habitat in the stream reach should not be sampled. In this case, the remaining jabs are allocated proportionately among the predominant substrates.

The second method, called the single-habitat method, calls for uniform sampling at designated spots within the sampling run. For this study, a single habitat was designated as being the bottom sediments near shore, found within a water depth of one meter. This coincides with the protocols for the USEPA's EMAP for non-wadeable streams. One jab is made at each of the 11 cross-sections marked by flags. A jab constitutes placing the net on the bottom sediments and disturbing the bottom for 0.5 m upstream of the net for a time interval of 30 seconds. This is similar to the kick method described in the multihabitat protocols. This method was chosen because it allows both wadeable and non-wadeable reaches to be sampled in the same manner. The intent was to try both methods to determine which worked best for the project.

3.5.1.1 Single-Habitat Sampling

Sampling was started at the downstream end of the reach and proceeded upstream, doing a jab at each flagged cross-section. The first jab was done on the left side of the stream (reference facing downstream). The next jab was done on the right side of the stream. Alternate sides of the stream were jabbed with progression upstream through the sampling reach. Each jab was composited in a bucket labeled SINGLE HABITAT. After all jabs had been composited in the bucket, the contents were washed into a sieve bucket. The sample was transferred from the sieve bucket to a sample container(s) and preserved in enough 95 percent ethanol (ETOH) to cover the sample. A river sample label was placed in the container indicating the sample site number, location, single- habitat sample, GPS coordinates of X site, date, and collector name. The first three parameters are preprinted on the labels; the rest were filled in by crewmembers. The outside of the container included the same information and the words "preservative: 95 percent ethanol." If more than one container was needed for a sample, each container label contained all the information for the sample and was numbered (e.g., 1 of 2, 2 of 2, etc.). The number of containers was recorded in the Sample Tracking Sheet at the biological laboratory.

Since a major advantage of this sampling protocol is that it is supposedly quicker than multihabitat sampling, the beginning and ending times were recorded on the River Field Data Sheet so that the validity of this assumption could be analyzed over the course of the summer. Beginning is the time jabs are first collected and ending is when all 11 jabs have been composited and placed in wide-mouth jars with 95 percent ETOH.

3.5.1.2 Multihabitat Sampling

Sampling was begun at the downstream end of the reach and proceeded upstream. The jabs or kicks collected from the multiple habitats were composited into a bucket labeled MULTIHABITAT to obtain a single homogeneous sample. Every three jabs, more often if necessary, the collected material was washed by running clean stream water through the net two to three times. If clogging occurred that might hinder obtaining an appropriate sample, this portion of the sample was discarded and sampling was redone in the same habitat type, but in a different location. Large debris was removed after rinsing and inspecting it for organisms; any organisms found were placed into the sample bucket. After all jabs were composited in the bucket, the contents were washed into a sieve bucket.

The sample was transferred from the sieve bucket to sample container(s) and preserved in enough 95 percent ETOH to cover the sample. Forceps were sometimes needed to remove organisms from the dip nets and sieve bucket. A river sample label indicating the sample site number, location, multihabitat sample, GPS coordinates of X site, date, and collector name was placed into the sample container. If more than one container was needed for a sample, each container label contained all the information for the sample and was numbered (e.g., 1 of 2, 2 of 2, etc.). The number of containers was recorded in the Sample Tracking Sheet at the biological laboratory.

On completion of sampling, the percentage of each habitat type in the reach was recorded on the River Field Data Sheet. The sampling gear used was noted as were conditions of the sampling, e.g., high flows, treacherous rocks, difficult access to stream, or anything that indicated adverse sampling conditions.

The number of jabs taken in each habitat type was recorded on the River Field Data sheet, as were beginning and ending time of sampling. Beginning was the time jab collection started and ending was when all 20 jabs had been composited and placed in wide-mouth jars with 95 percent ETOH.

After sampling had been completed at a given site, all nets, pans, etc., that came in contact with the sample were rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found were placed into the sample containers. The equipment was examined again prior to use at the next sampling site.

3.5.2 Summary of Results

The protocol called for identification of a subset of 300 individuals from the sample. Additional organisms above the 300 count were not enumerated. However, the total number of organisms collected in each sample was estimated. Since the samples were picked using a pan with grids, the total number of organisms in a sample could be estimated by calculating the number of organisms per grid and multiplying that number by the number of grids.

The first sampling had by far the fewest number of organisms per sample, with the multihabitat averaging 610 organisms and the single-habitat averaging 470 organisms per site. Many samples in this first sampling (May) did not even have 300 organisms. By contrast, the third sampling period (September) had a much higher average number of organisms, with the multihabitat averaging 4,660 organisms per sample and the single-habitat sampling averaging 2,400 organisms. Since the multihabitat had almost twice as many jabs, 20 compared to 11 for the single-habitat, these results are not surprising. It should also be noted that there was a wide variation among sites and sampling periods. One site in particular, site 16, had low numbers of organisms. Single-habitat sampling at site 16, with an average of 120 organisms, did not surpass 300 organisms in any of the three periods. Even the multihabitat sampling surpassed 300 only in the September sampling. It is interesting to note that this site did have a high diversity (see Site Data Sheets in Appendix C and Table 3 – Comparisons of Selected Metrics for Third Sampling). This site was located in the Sheyenne Valley National Grasslands and the streambed was characterized as being sandy with little structure. The lack of organisms at this site is probably due to poor habitat structure and not to human perturbations.

Not surprisingly, the multihabitat type of sampling was more likely to get at least 300 organisms for identification. This was especially apparent in the July sampling, where the single-habitat sampling had 10 sites with fewer than 300 organisms, whereas the multihabitat had only three sites with fewer than 300 organisms. In the third sampling, the multihabitat produced over 300 organisms for all 18 sites, whereas the single-habitat had four sites that did not reach the 300-organism amount.

The amount of sampling time required for the single-habitat was only slightly faster than the multihabitat. Over the summer, single-habitat sampling averaged 24 minutes a site and multihabitat averaged 29 minutes per site. Considering that setting up the extra flags for marking the single-habitat collection spots adds at least five minutes to the setup time, single-habitat sampling does not seem to provide any advantage in terms of time expended.

Table 3 shows a list of three metrics that were examined in the third sampling period: taxa richness, EPT index, and number of Ephemeroptera taxa. Taxa richness is the number of different taxa recorded at a site. EPT index is the number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa recorded at a site. These three insect orders are considered good indicators of water quality. The higher the EPT index, generally the better the water quality. The number of Ephemeroptera taxa is a subunit of the EPT index and is the most diverse of the three EPT taxa in the Sheyenne. The averages for the third sampling period metrics show that the multihabitat sampling resulted in slightly higher numbers in all three metrics. However, the averages are not significantly higher, suggesting that single-habitat does an adequate job of sampling the available organisms. This is a little surprising, since multihabitat protocols sample nearly twice the area and supposedly more of the available habitats than single-habitat protocols.

The comparison of metrics (Table 3) also shows an increase in taxa richness, EPT index, and Ephemeroptera with progression downstream. It should be cautioned that these changes might not be due to water quality changes but to changes in river size. A study of this type, which examines an entire river, should not directly compare upstream sites to downstream sites. These are very different areas of the river, and studies have shown that in general, larger rivers have more diversity because they have a larger and more diverse habitat. It would be expected that the downstream metrics would be intrinsically different than upstream metrics. It will be important in the future to document metrics for all areas of the river.

Table 4 shows the overall taxa list, which has 205 different taxa that were identified in this project. This table also shows which sites each taxon was collected in. Examination of this table shows several taxa to be fairly ubiquitous (i.e., chironomid larvae, *Caenis,* and *Hyallela azteca*), whereas several taxa are limited to certain areas of the river. For example, *Baetisca* and *Pentagenia*, two mayfly taxa, were only found in the downstream areas of the river.

3.5.4 Recommendations

Sample results for this project provide a good foundation for baseline conditions. However, one year of data is not enough to constitute a complete baseline for biomonitoring efforts. It is possible that the project data are biased because of the high water events this past spring and summer. If the outlet is to be built, it will be important to conduct additional macroinvertebrate sampling to establish a reliable baseline to provide sufficient background to realistically document changes in biota that may be caused by the outlet. In addition, it will be important to monitor the river every summer after the outlet begins functioning until the monitoring shows stabilization in the biota.

Preliminary examination of some rudimentary metrics seems to show that single- and multi-sampling protocols both do an adequate job of documenting the macroinvertebrate diversity when adequate numbers of organisms are collected. However, there are concerns that the single-habitat protocol doesn't always provide enough organisms to do a 300-count subsample. In those cases, the similarity in results between protocols is not as strong. Also, single-habitat collection does not result in a large savings of time and energy. Coupled with the fact that the NDDH uses the multi-habitat approach, indications are that further sampling protocols should consider focusing on multi-habitat type sampling. The point of using a protocol similar to the one used by the NDDH is that they are currently using their data to determine an Index of Biological Integrity specific for North Dakota rivers and streams. Since these data will be generated with multihabitat sampling, it is questionable whether it would be applicable to single-habitat collections. In summary, it is recommended that future sampling protocols focus on multihabitat sampling.

3.6 MUSSEL EXAMINATION OF WADEABLE SITES

3.6.1 Protocol Overview:

If mussels were found at a site that was wadeable, a mussel survey was done. This consisted of marking a 20 m section of the river containing the live mussels. Within this 20 m section, five one-meter square plots were picked at random. The number and types of mussels found in each plot were recorded on the River Field Data Sheet. Up to five mussels of each identified species were collected as voucher specimens. Any mussels that were not kept were carefully replaced in the bottom sediments.

3.6.2 Summary of Results

Unfortunately, for the first two sampling sessions, May and July, river flows were such that the majority of sites were not wadeable. Thus, no mussel surveys were done during these times. However, individual mussels were collected in the regular sampling at five sites that were non-wadeable. At Site 03 in May a single *Lampsilis siliquoidea* was collected. At Sites 05, 07, and 12 during July one *Pyganodon grandis* was collected at each site, and at Site 18 one *Lampsilis cardium* was collected in September.

In the last sampling session the water levels had receded to the point that most of the upstream sites were wadeable. Two wadeable sites, 03 and 09, had mussels and were surveyed. In both sites the original mussel found in the normal sampling was a *Pyganodon grandis.* The survey of Site 03 turned up 30 mussels total within the 5 one-meter-square plots. All were *Pyganodon grandis.* At Site 09, only four additional mussels were found — two were *Lampsilis cardium*, one was *Lampsilis silquoidea*, and one was *Pyganodon grandis.*

3.6.3 Recommendations

In reviewing past studies, it is apparent that many species of mussels were missed in the current project. This was due in part to the high-water conditions in both May and July. Even in September, several of the downstream sites were still not wadeable. This is important because Jensen (2001) stated that the majority of the mussels they found were in downstream areas. The few mussels found in this project were in upstream sites. In addition, two of the most common species seen by Jensen (2001) were not found. In fact, only three species of mussels were recovered in the current study.

There are several reasons for the poor mussel survey results. The sampling sites were not selected specifically for mussels; the protocol was dependent on the fact that mussels would occur within the 100 m reach of a site. Beds outside the reach were not examined. Finding mussels by sight is almost impossible in the Sheyenne; the streambed is not visible because of the turbid water. This, coupled with high-water conditions, made finding mussels rather difficult.

Sampling of mussels should be an integral part of the biological assessment of the Sheyenne River. Mussels are considered to be important components to any river community because of their role as filter feeders, their longevity, and their declining populations worldwide. Mussel sampling should be independent of the macroinvertebrate work. Sites already examined by the NDGFD could be examined, and different protocols using SCUBA or illuminated underwater cameras utilized.

4.0 LAKE SAMPLING

4.1 SITES SAMPLED

The general locations of the sites include three on Lake Ashtabula, five on Devils Lake, and one each on East and West Stump Lake. Lake Ashtabula is a long reservoir of the Sheyenne River created by Baldhill Dam. It runs approximately north to south and so sites were distributed as a north, a central, and south. Sites were numbered from south to north, so the southernmost is Site 19 and the northernmost is Site 21. On Devils Lake, two sites were established in West Bay, one in Main Bay, one in East Bay, and one in East Devils Lake. In addition, one site each on West Stump Lake and East Stump Lake was sampled. These sites were numbered from west to east from 22 to 28. A 20-foot pontoon owned by VCSU was used as the sampling vessel for all but one of the sites. The site on East Devils Lake (site 26) does not have an access ramp so a portable boat with electric trolling motor was used to access this site.

4.2 PROTOCOL OVERVIEW

Samples were taken with a 9" × 9" Ponar grab; a crane and winch were used to lower and raise the grab. Two to five grabs were done at each site. All grabs were composited in a large tub. To process the sample, organisms were washed off of any sticks, rocks, and similar-size objects back into the tub. After removal of rocks and sticks, the sample was mixed into fine, uniform slurry. After mixing, the slurry was sieved using a U.S. No. 30 sieve (595 micrometers [μm]) to remove organic and mineral material. The sieve retains the benthic organisms. The organisms in the sieve were washed into a large plastic wide-mouth jar. The jar was filled with 95 percent ETOH to approximate an overall final concentration of 70 percent ETOH. The jar was labeled with a standard Lake Sample Label. This label includes site number, site location, date, GPS coordinates, number of grabs in the sample, and number of jars filled for that site, if more than one jar is needed. The first two parameters were preprinted on the label, the rest were filled in on site.

On the first (May) sampling event, sites were selected if they had a fairly uniform bottom and were well away from the shore. It was originally planned that the depth should be eight to ten meters at these sites. However, at several sites it was difficult if not impossible to reach these depths. For instance, the North Ashtabula site (Site 21) does not get any deeper than five to six meters. The proposed depth limits were adjusted to five to ten meters. When a suitable site was located, the pontoon was anchored and GPS readings were recorded. A Garmin GPS III Plus with a nondifferential accuracy of 15 m was used. If there were visible landmarks on shore that aided in relocating the site, pictures were taken with a digital camera and the site was marked on the USGS topographic map. The number of pictures and a compass bearing of where they were taken were recorded on the Lake Field Data Sheet; as were general weather conditions, including air temperature, wind speed and direction, and sky conditions.

On subsequent trips to the site, the GPS readings, map, and landmark photos were used to get at or near the original site. In almost all cases, resampling occurred in the same proximity for each site. One exception was the Main Bay site (Site 24). At this site, the first sampling occurred in an area that was characterized by a rocky bottom. However, the Ponar grabs used in this project are designed for soft-bottomed substrates and do not work well on rocky bottoms. After several attempts, a sample was taken from Main Bay. In the subsequent sampling period in July, a representative sample could not be obtained from this area. Main Bay presented two problems: one was the rocky bottom and the second was the depth of the lake. This area of the lake gets deeper than 10 meters rather quickly. Over an hour

was spent trying to find a suitable site, which is shown in Appendix D. This site was actually located in Creel Bay, which is just off Main Bay, and it was the best site that could be found to fit project needs. The September sampling was done at this spot also.

4.3 WATER QUALITY MEASUREMENTS

After the site was established and the boat anchored, the Hydrolab was lowered to within 0.5 m of the lake bottom. Standard procedures were followed to record the turbidity, pH, temperature, DO, and depth. The Hydrolab measurements were done before the Ponar grabs to minimize the interference of a disturbed bottom. Also, the Hydrolab was lowered off the front of the pontoon, as far away from the anchor as possible.

4.3.1 Summary of Results

Graphs and data for the lake water quality measurements are included in Figures 9 through 13. Examination of the data reveals expected seasonal variations in temperature and DO, as well as the well-documented increase in conductivity moving from west to east in the Devils Lake chain and into West and East Stump Lake (see Figure 12).

4.4 BENTHIC MACROINVERTEBRATES

The crane and winch were used to lower the Ponar grab. When the grab was within a meter of the bottom of the lake, the descent was paused and then slowly resumed to put the grab on the bottom. This was done to try and eliminate a pressure wave moving out from the grab as it strikes the bottom. After the grab tripped and closed, it was raised using the winch. It was pulled up, examined to ensure that debris did not prevent it from closing properly, swung onto the deck of the pontoon, and dumped into a large tub. The contents of the sediments were examined to get an estimate of how many organisms were collected in the grab. The number of additional grabs necessary to achieve at least 200 organisms was estimated. The additional grabs were done in a similar manner, and were taken from an area close to, but not exactly over, the previous grabs. The total number of grabs was recorded on the Lake Field Data Sheet.

4.4.1 Summary of Results

Lakes in general have rather low macroinvertebrate diversity, especially at deeper depths. The main macroinvertebrates in project samples were chironomids, oligochaetes, other dipteran larvae, and some mollusks. The decision was made to also count major zooplankton, such as daphnia and copepods, because of their abundance. In some of the Devils Lake samples there were considerable numbers of amphipods (*Gammarus* sp*)*. Many, if not all, were probably caught in the dredge during its descent, as there are large numbers of *Gammarus* in the open waters of Devils Lake.

During lab processing of the samples it became apparent that they had much higher numbers of individuals than estimated. In many sites, one grab may have been sufficient. Complete species lists and counts are found in Appendix C.

5.0 LAB PROCESSING AND STORAGE

5.1 LAB OPERATIONS OVERVIEW

Once samples were brought back to the lab, they were checked in and recorded on either the River or Lake Sample Tracking Sheet. The samples were stored until ready for sorting, counting, and identification. All sorting, identifications, and storing took place at Dr. DeLorme's macroinvertebrate lab at VCSU.

A fixed-count subsampling method was used. The protocol below has been used by Dr. DeLorme to subsample and identify samples from the Sheyenne and routinely provides sufficient numbers and diversity of organisms. For lake samples a 200-organism count was used, and for river samples a 300-organism count was used. All organisms, even those not included in the count, were saved and stored at VCSU on completion of the sorting and identifying process. Identification of samples was to the lowest taxon possible. A voucher collection was prepared for each site and an overall voucher collection for the entire sampling period was prepared.

5.2 WASHING AND PREPARATION OF SAMPLES

Samples were thoroughly rinsed in a 500-µm-mesh sieve to remove preservative and fine sediment. Large organic material (whole leaves, twigs, algal, or macrophyte mats, etc.) not removed in the field was rinsed, visually inspected, and discarded. Since the samples had been preserved in alcohol, it was necessary to soak the sample contents in water for about 15 minutes to hydrate the benthic organisms to prevent them from floating on the water surface during sorting. If the sample was stored in more than one container, the contents of all containers for a given sample were combined at this time.

After washing, contents of the sample were spread evenly across a pan marked with numbered grids approximately 6 cm × 6 cm. Along the sides and top of the gridded pan, numbered jars were lined up to hold the sorted organisms. Based on experience, the process began with jars 1 to 15 set up, with jars 15 to 30 available if needed. If the sample was identified that day, these jars could contain water. If it was towards the end of the day and the sample would not be identified within the next twelve hours, 70 percent ETOH was used in the jars.

5.3 SAMPLE SORTING AND COUNTING

Using a deck of cards that contains numbers corresponding to the grids in the pan, a card was drawn to select a grid within the gridded pan. This was done to make sure sampling was random. Organisms were picked from that square and placed in the numbered jars. Any organism that was lying over a line separating two grids was considered to be on the grid containing its head. In those instances where it was not possible to determine the location of the head (worms for instance), the organism was considered to be in the grid containing most of its body. Each numbered jar contained one taxon of organisms. A tally counter was used to keep track of the total number of organisms. The tally counters were also used to keep track of specific taxa (i.e., scuds or corixids) that were in high abundance. When all organisms had been removed from the selected grid, another card was drawn and all the organisms from that grid were removed in the same manner. If new taxa were found, they were placed in the next empty jar. This process of drawing cards and picking grids continued until 10 grids had been picked. After 10 grids had been picked, the average number of organisms per grid was determined to approximate the total number

of grids that needed to be picked to reach 200 (for lake samples) or 300 (for river samples). When that number of grids was approached, the total count of organisms was monitored. A sample should not be stopped in the middle of picking a grid, so the picker stopped on a grid that gave a number as close to 200 or 300 as possible. This was done to eliminate any bias as to which organisms would be picked in the last grid. Rarely was the final count exactly 200 or 300 organisms. The number of grids that were picked to get the final count was noted on the bench data sheet. The remaining unsorted sample debris residue was saved in a separate container labeled "sample residue"; the original sample label was included in this container.

The picker wrote down the tentative identifications and total numbers of organisms for each jar on the Lab Data Sheet. Jars were examined under a 10× dissecting scope to count organisms and ensure that all organisms in a jar were of the same taxon. There was no attempt to separate taxa that were hard to differentiate; this was done under higher power during the final identification. Once all jars had been recorded on the bench sheet, screw tops were placed on the jars and the jars and bench sheet were placed on a designated tray and brought over to the final identification station.

After laboratory processing was complete for a given sample, all sieves, pans, trays, etc., that had come in contact with the sample were rinsed thoroughly, examined carefully, and picked free of organisms or debris; organisms found were added to the sample residue.

5.4 SAMPLE IDENTIFICATION

Most organisms were identified to the lowest practical level (generally genus or species) using a dissecting microscope. Midge larvae (Diptera: Chironomidae) were identified to the subfamily level in most cases. The chironomid group is an especially difficult group to identify to genus, and because of the short time period allotted for this project they were identified to the subfamily level. One common specimen from the lake samples, *Chironomus*, was recorded to genus. Representative chironomid larvae were mounted on slides. All other chironomid larvae were saved in vials separate from the site voucher collections in the event further identification work was deemed important in the future. Oligochaetae were mounted on slides in an appropriate medium and identified to at least the family level using a compound microscope (see Section 5.5).

Each taxon found in a sample was recorded and enumerated in a laboratory bench sheet. Any difficulties encountered during identification (e.g., missing gills) were noted on these sheets. Also noted on the bench sheet were the life stage of the organisms and the taxonomist's initials. After each taxon was identified, the organisms were placed in a container labeled with the site number, location, and date. This container, along with any slides, constituted the voucher collection for that site. After the sample had been identified, properly labeled, and placed in 70 percent ETOH, it was cataloged and placed in the North Dakota River and Stream Macroinvertebrate Collection. This collection is located adjacent to Dr. DeLorme's macroinvertebrate lab at VCSU. Location of sample and date of placement in the collection were recorded on the Sample Tracking Sheet.

5.5 SLIDE PREPARATION

Representative midge (Chironomidae) larvae and pupae were mounted on slides in an appropriate medium (e.g., Euperal, CMC-10); slides were labeled with the site identifier, date collected, and the first initial and last name of the collector. As with midges, worms (Oligochaeta) were also mounted on slides

and appropriately labeled. All slides will be kept in the North Dakota River and Stream Macroinvertebrate Collection.

5.6 SAMPLE VOUCHERS AND STORAGE

Individual specimens of each taxon were extracted from the samples to prepare a voucher collection for the project. These individuals were placed in specimen vials and tightly capped. A label with the site, date, taxon, and identifying taxonomist was placed inside the vial. A separate label was added to some slides to include the taxon (taxa) name(s) for use in a voucher or reference collection.

To archive samples, specimen vials (grouped by voucher collection station, and date), were placed in jars with a small amount of denatured 70 percent ETOH and tightly capped. The ETOH level in these jars will be examined periodically and replenished as needed. A stick-on label indicating sample identifier, date, and preservative (denatured 70 percent ETOH) was placed on each jar. These voucher collections were cataloged and placed in the North Dakota River and Stream Macroinvertebrate Collection located at VCSU.

TABLES

TABLE 1

SITE LOCATIONS AND GPS COORDINATES FOR SUMMER 2001 MACROINVERTEBRATE SAMPLING

STATION ID	LOCATION	LAT_DEC	LONG_DEC
AC01	East of Sheyenne Lake	47.6605	-100.0978
AC02	West of Peterson Coulee	47.7977	-99.8325
AC03	NW of Peterson Coulee	47.9072	-99.4116
AC04	Peterson Coulee	47.8863	-99.3859
AC05	4 Miles NE of Sheyenne	47.8542	-99.0390
AC06	1½ Miles E of Goose Lake	47.8330	-98.9390
AC07	S of Pekin	47.7489	-98.2911
AC08	7 Miles W of Aneta	47.6864	-98.1296
AC09	NE of Highway 65 & 45 Junction	47.5983	-98.1216
AC10	6½ Miles NE of Cooperstown	47.4668	-98.0083
AC11	Below Baldhill Dam	47.0151	-98.1017
AC12	VCSU Campus Footbridge	46.9200	-98.0031
AC13	Miller's Crossing	46.8960	-98.0108
AC14	5 Miles N of Kathryn	46.7606	-97.9823
AC15	2½ Miles N of Fort Ransom	46.5581	-97.9115
AC16	Sheyenne Grasslands	46.5253	-97.3133
AC17	3 Miles E of Kindred	46.6348	-96.9695
AC18	1 Mile S of Harwood	46.9586	-96.9002
AC19	South Lake Ashtabula	47.0600	-98.0645
AC20	Central Lake Ashtabula	47.1328	-98.0336
AC21	North Lake Ashtabula	47.2350	-97.9745
AC22	West Bay #1 Devils Lake	48.0714	-99.2231
AC23	West Bay #2 Devils Lake	48.0835	-99.2389
AC24	Main Bay Devils Lake	48.0715	-98.9339
AC25	East Bay Devils Lake	48.0599	-98.8891
AC26	East Devils Lake	47.9462	-98.6024
AC27	West Stump Lake	47.8694	-98.3536
AC28	East Stump Lake	47.9151	-98.3925

TABLE 2

SUMMARY OF HABITAT SCORES

POOL SUBSTRATE CHARACTERIZATION																		
Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
First sampling	12	18	13	11	8	10	15	11	11	11	10	12	15	15	15	10	11	10
Second sampling	12	16	12	13	10	10	14	12	11	10	12	10	12	16	16	14	11	10
Third sampling	11	18	15	11	8	9	16	10	13	13	13	12	13	16	14	13	12	9
Channel Flow Status																		
Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
First sampling	18	16	17	18	19	19	19	17	17	18	19	19	19	18	18	18	19	17
Second sampling	14	16	16	16	16	16	16	17	16	16	18	19	16	18	17	18	18	15
Third sampling	7	15	14	15	16	14	16	13	16	13	16	16	13	13	14	16	14	15
Vegative Protection																		
Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
First sampling	18	16	18	18	16	14	16	14	16	16	16	16	16	16	18	18	15	15
Second sampling	18	17	18	18	18	17	18	16	18	16	18	16	18	18	18	18	16	16
Third sampling	18	18	16	18	17	17	18	12	18	16	18	18	18	18	18	18	18	14
Riparian Zone Width																		
Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
First sampling	16	18	18	18	16	16	18	14	18	18	18	12	16	18	16	18	16	11
Second sampling	18	17	18	16	17	16	18	16	18	18	18	10	17	16	17	18	17	13
Third sampling	18	18	18	14	17	16	18	18	18	16	18	14	18	18	18	18	18	10
Total Score																		
Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
First sampling	64	68	66	65	59	59	68	56	62	63	63	59	66	67	67	64	61	53
Second sampling	62	66	64	63	61	59	66	61	63	60	66	55	63	68	68	68	62	54
Third sampling	54	69	63	58	58	56	68	53	65	58	65	60	62	65	64	65	62	48

TABLE 3

COMPARISON OF SELECTED METRICS FOR THE THIRD SAMPLING SESSION

, , and

Site #	Taxa richness[1]		EPT[2]		Ephemeroptera[3]	
	Single	Multi	Single	Multi	Single	Multi
1	17	22	1	1	1	1
2	21	19	4	5	2	2
3	18	20	2	2	2	2
4	24	28	5	6	4	3
5	22	32	2	6	1	3
6	28	27	5	6	3	3
7	17	23	3	5	3	4
8	24	18	5	5	4	2
9	26	21	10	6	7	4
10	23	24	8	8	6	7
11	24	29	8	9	4	6
12	30	33	7	9	4	5
13	25	26	10	10	8	8
14	25	25	9	9	7	7
15	24	31	10	11	8	8
16	27	31	13	13	8	9
17	22	38	11	16	7	11
18	20	26	11	11	7	7
Ave.	23.2	26.3	6.9	7.7	4.8	5.1

Note:

[1] Taxa richness refers to the total number of taxa identified in a sample.

[2] EPT refers to the number of Ephemeroptera, Plecoptera, and Trichoptera taxa recorded.

[3] Ephemeroptera refers to the number of Ephemeroptera taxa recorded at that site.

TABLE 4

COMPLETE TAXA LIST FOR ALL SAMPLING

FINAL ID	SITES IN WHICH THE TAXA WAS RECORDED
Acentrella	6, 7, 8, 9, 10, 13, 14, 16
Acroneuria	18
Aeshna	4
Agabus	1
Amnicola limosa	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15
Anax junius	2
Anthopotamus	9, 10, 11, 12, 13, 14, 15
Arachnida	4, 5, 6, 7, 12, 14, 15, 16, 17, 18, 26
Argulus	6, 7, 18
Asynarchus	6
Atherix	2, 14, 16, 17, 18
Baetidae	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Baetis	2, 4, 6, 9, 10, 11, 13, 14, 17, 18
Baetisca	14, 15, 16
Belostoma flumineum	2, 4, 6, 7, 11, 12, 16
Belostomatidae	6
Berosus	1,4
Bezzia	1, 3, 9, 11, 18
Brachycentrus	10, 14, 16, 17, 18
Brachycera	6, 26
Braconidae	5
Branchiobdellidae	3, 13
Caenis	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21
Calanoida	11, 12, 19, 22, 23, 24, 25, 26, 27, 28
Callibaetis	26
Callicorixa	1, 9
Calopteryx	4, 7, 13
Candona	21, 22, 23
Candonidae	26
Carabidae	3, 17
Centroptilum	3, 5, 6
Ceratopogon	6
Ceratopogonidae	4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 17, 18
Ceratopsyche	2, 3, 4, 10, 11, 12, 13, 14, 15, 16, 17, 18
Cercobrachys	8, 10, 15, 16, 17, 18
Ceriodaphnia	1, 2, 3, 4, 7, 12, 21, 26
Chaoboridae	19
Chaoborus	19, 20, 26
Cheumatopsyche	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 24
Chironomidae	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 28
Chironominae	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28

TABLE 4

COMPLETE TAXA LIST FOR ALL SAMPLING
(continued)

FINAL ID	SITES IN WHICH THE TAXA WAS RECORDED
Chironomus	1, 5, 6, 7, 8, 10, 12, 19, 20, 21, 22, 23, 25, 27, 28
Chrysops	5, 9, 10, 13, 14, 15, 17
Cincinnatia cincinnatiensis	6, 7, 9, 10, 14, 15, 21
Coenagrionidae	1, 2, 4, 5, 11, 12, 17, 18
Coleoptera	3, 18
Collembola	6, 8
Corixidae	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20, 21, 26, 27
Cymatia americana	12
Cyphon	14
Cypridopsis	27
Daphnia	1, 2, 11, 12, 13, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28
Daphnidae	20, 22, 23, 25
Decapoda	8, 11, 14
Diaptomus	1, 7, 11, 12, 13, 14, 19, 20, 22, 23, 24, 25, 26, 27, 28
Diptera	1, 7, 8, 9, 10, 12, 14, 15, 16, 17, 18
Dolichopodidae	6
Dubiraphia	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18
Elateridae	4
Ellipes minuta	16
Empididae	6, 7, 11, 13
Enallagma	3, 4, 5, 9, 11, 12, 13
Enochrus	14
Ephemeroptera	1, 10, 15, 17
Ephoron	7, 8, 9, 10, 13, 14, 15, 18
Ephydra	1
Ephydridae	3, 11, 14, 17, 18
Erioptera	15
Erpobdella punctata	1, 2, 7
Erpobdellidae	1, 2, 5, 11
Ferrissia	3, 4, 5, 6, 7, 9, 11, 12, 13
Folsomia	7
Gammarus	1, 22, 23, 24, 25, 26, 27, 28
Gastropoda	10, 13, 25
Gerridae	7
Glossiphoniidae	1, 3, 16
Gomphidae	6, 8, 15, 16, 17, 18
Gomphus	5, 6, 8, 9, 10, 11, 13, 14, 15, 16
Gyraulus	18
Gyraulus parvus	4, 5, 12
Gyrinidae	2

TABLE 4

COMPLETE TAXA LIST FOR ALL SAMPLING
(continued)

FINAL ID	SITES IN WHICH THE TAXA WAS RECORDED
Gyrinus	6, 11
Haeterina	11
Haliplus	1, 5, 7, 9, 13
Helichus	17
Helisoma	2
Helobdella stagnalis	1, 4
Helophorus	3, 6
Hemerodromia	6, 8, 11, 13, 14
Hemiptera	2, 5, 9
Heptagenia	8, 10, 13, 14, 15, 16, 17, 18
Heptageniidae	2, 3, 4, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18
Hesperocorixa	3, 12, 13, 17
Hetaerina	17
Heteroceridae	15, 17, 18
Hexagenia	4, 6, 10, 11, 12, 17
Hexagenia limbata	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Hexatoma	14, 15
Hirudinea	4
Hyalella azteca	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 20, 26, 27
Hydracarina	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 14, 15, 18, 19, 20, 21, 22, 23, 24, 26
Hydrobiidae	5, 6
Hydrochus	18
Hydroporus	6, 17
Hydropsyche	8, 9, 10, 14, 15, 16, 17, 18
Hydropsychidae	2, 9, 11, 13, 16
Hydroptila	2, 5, 11
Hydroptilidae	18
Hygrotus	4
Hymenoptera	8
Ichneumonidae	18
Isonychia	9, 10, 14, 17, 18
Isoperla	16, 17
Labiobaetis	3, 4, 6, 7, 12, 13, 14, 16, 17, 18
Laccophilus	1, 2
Lampsilis cardium	18
Lampsilis siliquodea	3, 9
Lepidoptera	6, 18
Leptoceridae	6, 10, 11, 14, 20
Leptophlebia	9
Leucrocuta	7, 9, 13, 14, 15, 18

TABLE 4

COMPLETE TAXA LIST FOR ALL SAMPLING
(continued)

FINAL ID	SITES IN WHICH THE TAXA WAS RECORDED
Limnephilidae	4, 6, 7, 8, 9, 10, 12, 15, 16, 17
Limnephilus	3
Liodessus	1, 4, 5, 9, 12, 15, 16, 17
Lymnaeidae	3, 16
Macronychus	16, 17, 18
Mayatrichia	18
Mesocyclops	1, 2, 4, 6, 7, 12, 14, 15, 20, 21, 22, 23, 24, 25, 26, 27, 28
Naididae	1, 7, 10, 19
Nectopsyche	3, 4, 6, 7, 8, 10, 13, 14, 15, 16, 17, 18
Nematoda	1, 2, 5, 9, 11, 12, 13, 14, 20, 23
Nemotelus	14
Neoplea	4, 5, 6, 8, 11, 12, 15, 17, 18
Neotrichia	18
Neureclipsis	11
Neureclipsis bimaculata	11
Notiphila	1
Ochthebius	9, 17, 18
Oecetis	2, 3, 4, 5, 6, 8, 11, 12, 20, 24, 26
Oecetis cinerascens	2
Oecetis nocturna	3, 4
Oligochaeta	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26
Onychiuridae	18
Orconectes	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Ormosia	6, 8, 10, 15, 16
Orthocladiinae	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 26
Ostracoda	1, 2, 5, 8, 21, 22, 23, 25, 26, 27
Palmacorixa	4, 5, 6
Palmacorixa buenoi	1, 6, 12
Palmacorixa gillettei	2, 3, 6, 11, 15, 18
Paranyctiophylax	12
Peltodytes	1, 3, 4, 5, 9, 11, 12, 16, 17
Pentagenia	15, 16, 17, 18
Perlodidae	17
Physa	1, 2, 3, 4, 5, 6, 11, 12, 26
Physa gyrina	7, 18
Pisidium	2, 3, 4, 5, 7, 8, 11, 12, 13, 14, 15, 19, 20, 21
Placobdella ornata	3, 5
Planorbidae	2
Plecoptera	17
Polycentropodidae	14

TABLE 4

COMPLETE TAXA LIST FOR ALL SAMPLING
(continued)

FINAL ID	SITES IN WHICH THE TAXA WAS RECORDED
Polycentropus	3, 4, 5, 12
Potamyia	18
Probezzia	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 26
Probythinella lacustris	6, 12
Procloeon	5
Protoptila	11
Psychomyia	4
Pycnopsyche	7, 10, 11, 13
Pyganodon grandis	3, 5, 9, 12, 21
Pyrrhalta	4
Ranatra fusca	4, 5, 6
Rhaphium	18
Rheumatobates	9, 11, 12, 14, 17, 18
Scatella	4, 8, 16
Scirtes	18
Scirtidae	12
Sialis	3, 4, 6, 7, 9, 12, 18
Sigara	1, 3, 5, 7, 8, 9, 11, 12, 13, 14, 15, 16
Sigara lineata	3, 11, 12, 13, 14, 15, 16, 17, 18
Simuliidae	2, 13
Simulium	2, 3, 9, 11, 13, 14, 16, 17, 18
Sminthuridae	6, 7
Sphaeriidae	2, 21, 24
Sphaerium	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 20, 21, 22
Stagnicola caperata	4, 6, 9
Stagnicola elodes	5
Staphylinidae	3, 11, 18
Stenacron	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Stenelmis	9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
Stenonema	6, 7, 8, 9, 10, 13, 14, 15, 16, 17, 18
Stenopelmus	18
Stenus	17, 18
Stratiomyidae	2, 4
Stylurus	6, 15, 16, 17
Tanypodinae	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28
Thysonaptera	13
Tipula	16, 17
Tipulidae	3, 13, 14, 16
Trichocorixa	1, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, 16, 17, 18
Tricorythodes	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18

TABLE 4

COMPLETE TAXA LIST FOR ALL SAMPLING
(continued)

FINAL ID	SITES IN WHICH THE TAXA WAS RECORDED
Tropisternus	16
Tubificidae	3, 12
Turbelaria	24
Valvata tricarnata	3, 5, 21

FIGURES

FIGURE 1

RIVER DISCHARGE MEASUREMENTS IN CFS

Flow (Total Q)			
Site #	**First**	**Second**	**Third**
1	40.87	11.72	0.75
2	49.68	41.2	6.43
3	188.92	184.96	16.17
4	222.46	161.47	13.87
5	235.79	112.78	
6	237.58	238.36	16.56
7	316.11	126.71	47.95
8	-	149.96	36.97
9	358.43	137.86	37.2
10	-	153.6	43.32
11	551.34	228.03	42.9
12	553.21	-	63.37
13	-	145.73	63.66
14	622.65	191.68	44.64
15	428.74		58.48
16	485.9	262.78	92.3
17	771.93	-	-
18	925.38	-	-

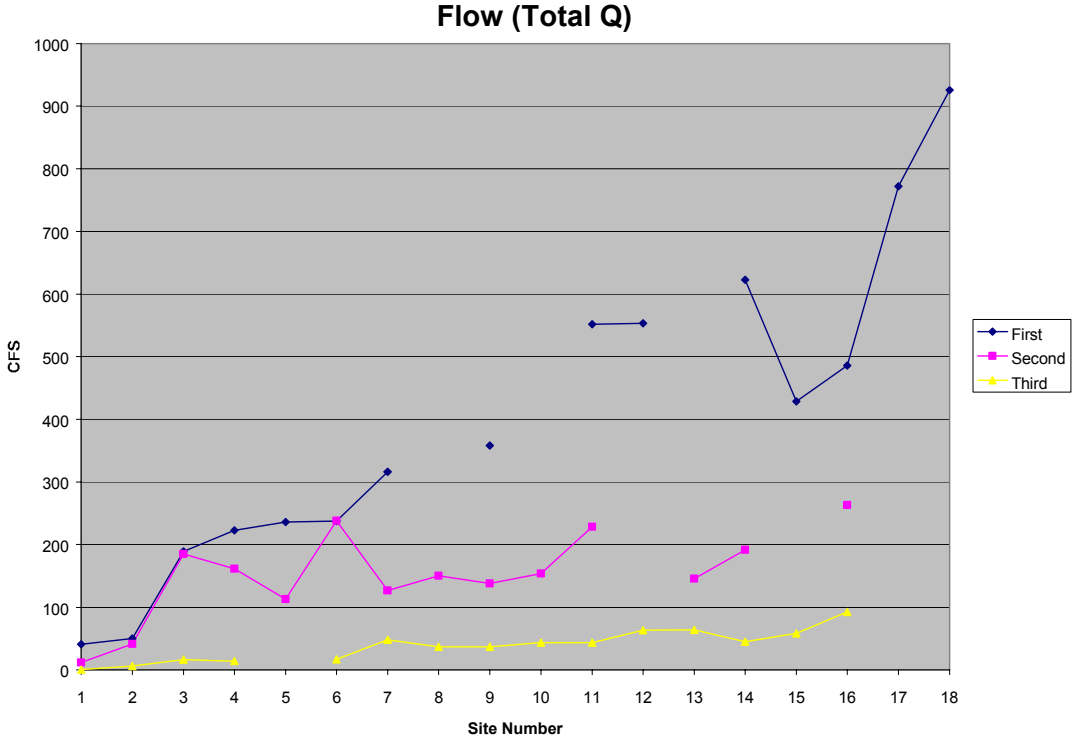

FIGURE 2

RIVER TEMPERATURE IN DEGREES CELSIUS

Water Temperature in degrees Celsius			
Site #	First Sampling	Second Sampling	Third Sampling
1	15.83	22.11	21.67
2	20.59	24.72	15.71
3	16.86	26.5	13.22
4	18.12	24.47	13.65
5	10.95	26.3	14.18
6	12.37	27	17.28
7	10.63	28.15	16.1
8	10.95	27.25	16.22
9	11.61	26.19	15.27
10	11.04	25.66	16.08
11	15.51	23.55	16.67
12	17.18	26.78	15.8
13	18.33	25.09	16.51
14	15.26	25.88	15.67
15	18.11	24.27	14.9
16	19.03	24.68	16.52
17	17.17	22.91	15.67
18	17.48	24.23	15.53

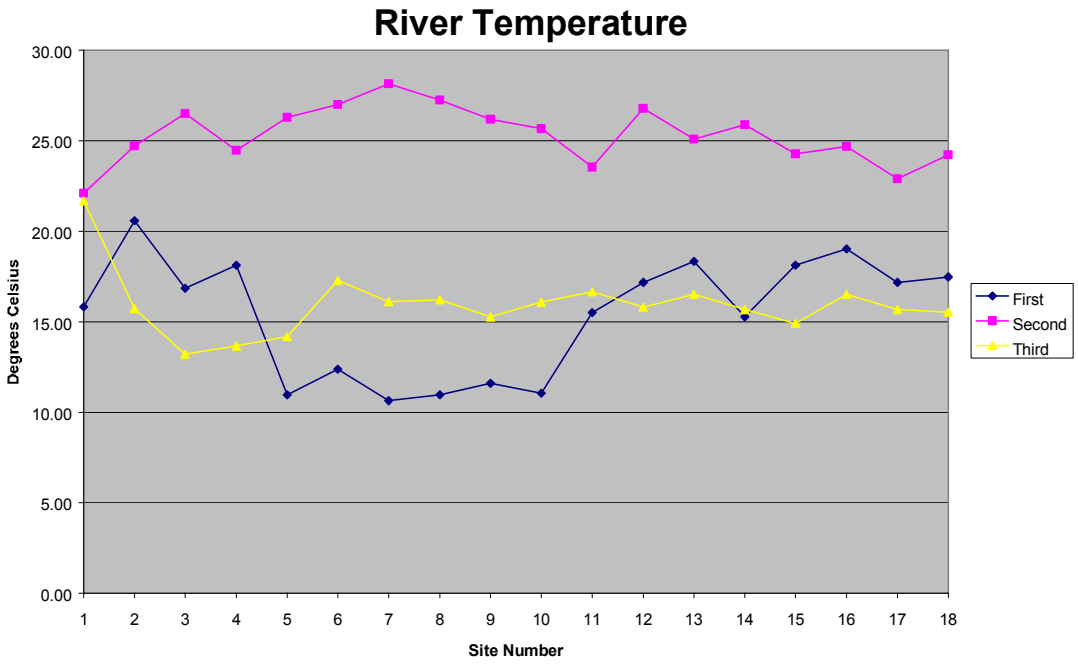

FIGURE 3

RIVER DISSOLVED OXYGEN IN MG/L

Dissolved Oxygen in mg/l			
Site #	First Sampling	Second Sampling	Third Sampling
1	3.87	2.6	7.783
2	8.55	7.88	7.12
3	6.45	5.88	7.97
4	6.34	5.29	8.19
5	7.91	4.79	6.36
6	7.82	4.96	7.39
7	9.75	5.44	8.94
8	9.08	5.82	9.29
9	9.70	5.39	8.9
10	10.15	6.26	12.3
11	9.32	6.94	7.17
12	7.30	7.21	8.52
13	7.90	7.09	9.98
14	7.71	6.57	9.34
15	7.60	6.95	8.56
16	8.16	8.8	10.1
17	7.60	8.04	9.36
18	8.50	7.54	9.97

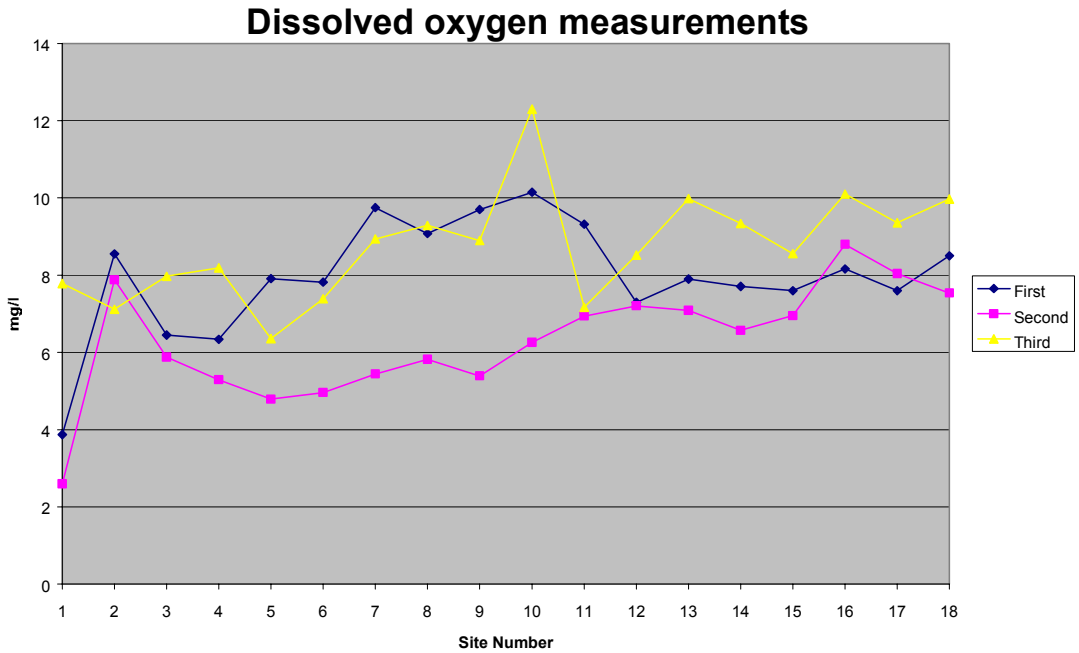

FIGURE 4

RIVER TURBIDITY IN NTUS

Turbidity in NTUs			
Site #	First Sampling	Second Sampling	Third Sampling
1		25.6	49.9
2		9.6	31.2
3		81.7	55.7
4		91.5	141.3
5	55.4	57.7	354.8
6	41.9	96.7	65.4
7	43.5	50.4	30
8	30	62.2	28.1
9	31.5	68.5	34
10	36.1	89.6	28.8
11		22.7	26.5
12	31.5	35.8	57.6
13	32.2	53.3	67.2
14	74.4	74.9	82.1
15	83.8	132.2	184.4
16	113.1	82.6	59.5
17	153.7	107.5	72.5
18	223.6	189.7	124.8

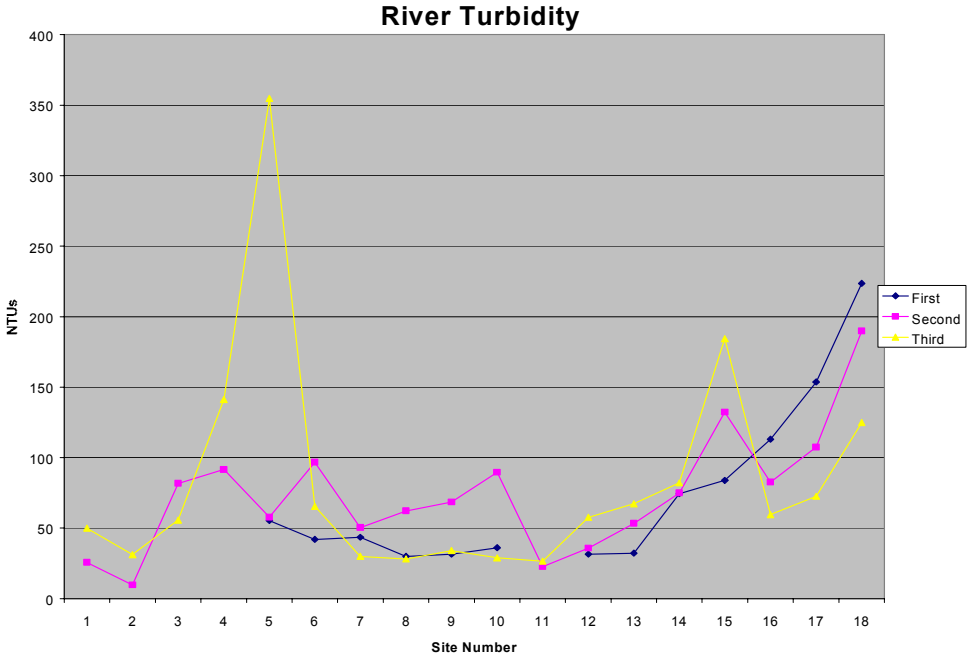

FIGURE 5

RIVER SPECIFIC CONDUCTIVITY IN µS/cm

Specific Conductivity			
Site #	**First**	**Second**	**Third**
1	1.45	1.231	0.7054
2	1.44	1.156	1.376
3	1.429	1.287	1.324
4	1.444	1.202	1.333
5	1.466	1.268	1.258
6	1.453	1.256	1.204
7	1.296	1.128	1.031
8	1.278	1.086	0.9782
9	1.284	1.117	0.9684
10	1.299	1.099	0.9586
11	0.8266	0.9143	0.9815
12	0.8515	0.8889	1.004
13	0.8607	0.9196	1.012
14	0.8877	0.937	1.04
15	0.9774	0.9035	1.024
16	0.9888	0.9257	0.9581
17	0.9658	0.8159	0.892
18	1.062	0.7239	0.9252

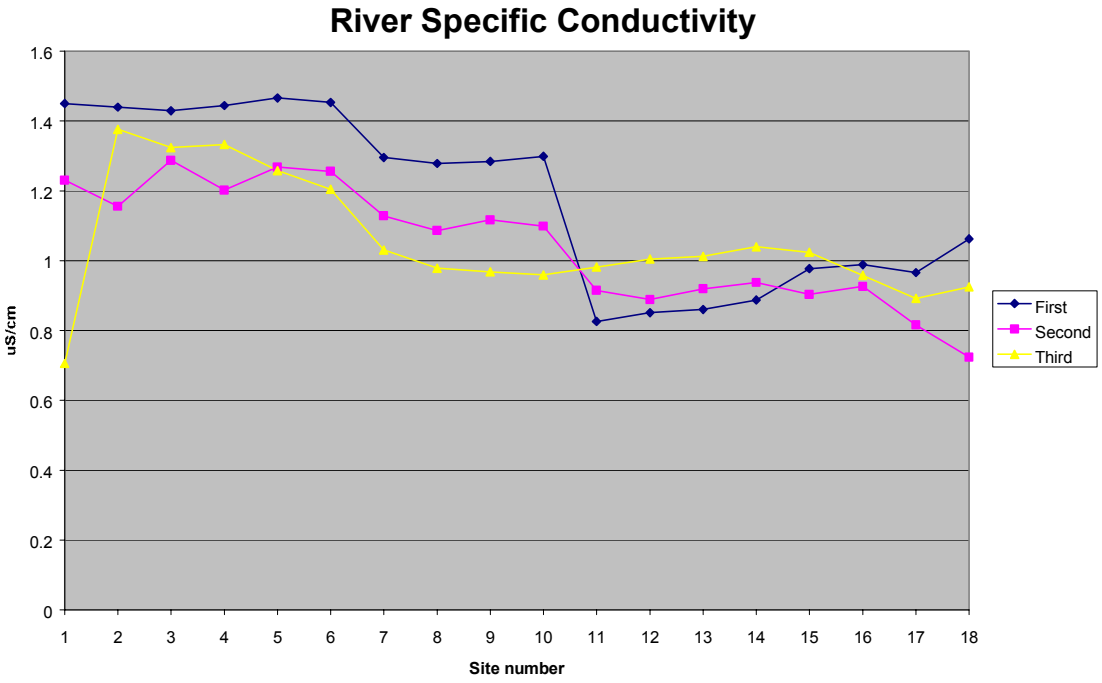

FIGURE 6

RIVER pH LEVELS

pH levels

Site #	First	Second	Third	Site #	First	Second	Third
1	7.98	7.79	7.89	10	8.49	8.43	8.45
2	8.68	8.41	8.56	11	8.35	8.58	8.54
3	8.42	8.31	8.41	12	8.41	8.49	8.43
4	8.35	8.32	8.51	13	8.38	8.4	8.45
5	8.56	8.23	8.31	14	8.28	8.36	8.51
6	8.54	8.29	8.24	15	8.43	8.39	8.28
7	8.61	8.4	8.44	16	8.38	8.57	8.46
8	8.55	8.36	8.41	17	8.38	8.45	8.38
9	8.52	8.39	8.49	18	8.36	8.39	8.35

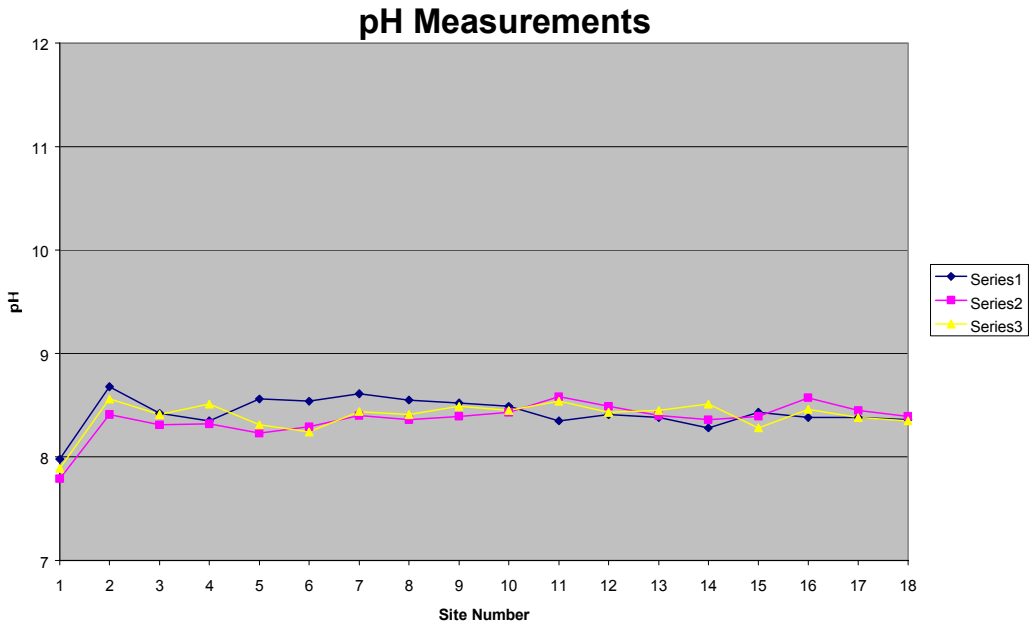

FIGURE 7

RIVER DEPTH AT THE MIDDLE OF THE X SITE
ALL MEASUREMENTS ARE IN METERS

River Depth in meters at Middle of X			
Site #	First Sampling	Second Sampling	Third Sampling
1	0.6	0.55	0.18
2	0.44	0.35	0.35
3	1.75	1.56	1.07
4	1.3	1.18	0.73
5	1.51	1.16	0.915
6	1.39	1.44	0.78
7	1.58	1.16	0.91
8	1.91	1.32	1.04
9	2.05	1.39	1.11
10	1.89	1.24	0.89
11	1.53	0.88	0.65
12	1.98	1.85	1.69
13	1.38	0.54	0.32
14	1.6	0.9	0.65
15	1.45	1.3	0.68
16	1.47	0.92	0.56
17	3.28	2.35	2.5
18	2.75	1.13	0.53

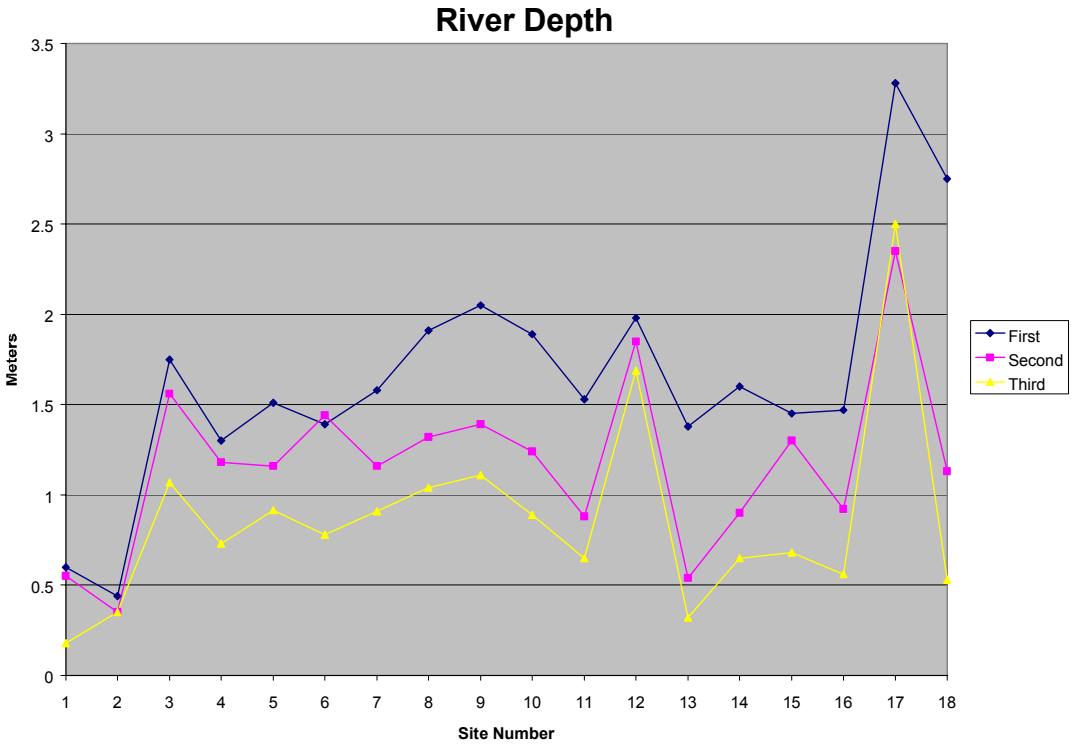

FIGURE 8

RIVER WIDTH AT THE X SITE
ALL MEASUREMENTS IN METERS

River Width in meters at X			
Site #	First Sampling	Second Sampling	Third Sampling
1	20	18	6.7
2	7.5	8.5	6.8
3	15.5	13.5	12.8
4	27.5	28	26.6
5	33	27.8	13.2
6	18	18.7	14.6
7	23	23.3	22.7
8	22.2	20	17.2
9	24	24.4	22.2
10	25	19.4	17.2
11	20	20	18.6
12	40.55	38.2	38
13	24	20.7	19.3
14	24.6	20.4	19.3
15	24	24.8	22
16	21	21.5	18.3
17	15.5	13.8	12.1
18	19.6	17.85	14.8

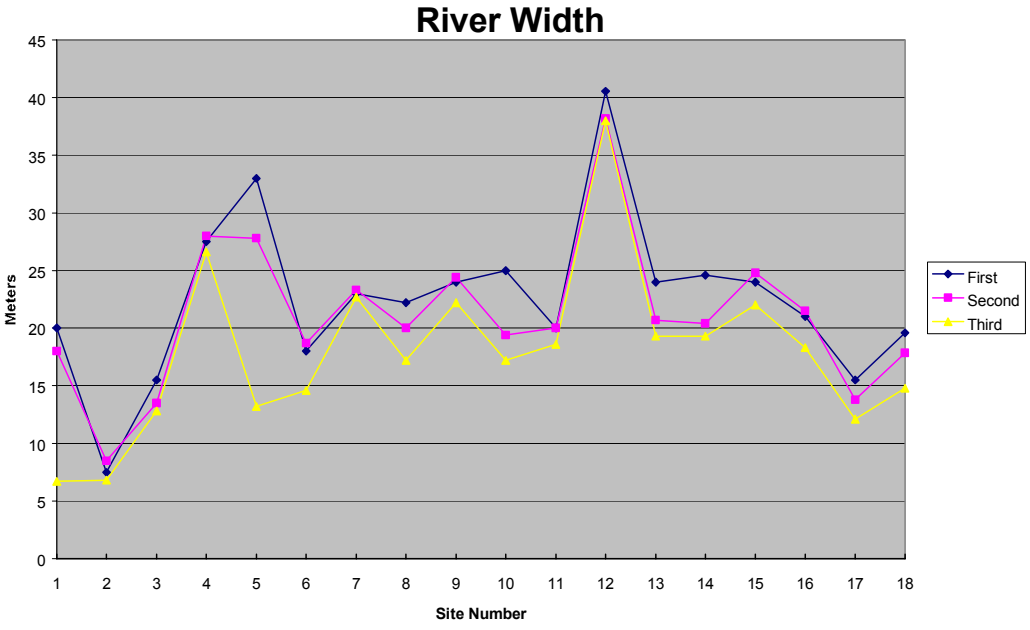

FIGURE 9

LAKE TEMPERATURES IN DEGREES CELSIUS

Temperature			
Site #	First Sampling	Second Sampling	Third Sampling
19	16.12	24.27	22.02
20	16.66	22.94	16.25
21	11.54	23.32	15.08
22	16.1	25.33	15.48
23	16.24	24.7	15.32
24	12.3	22.29	17.83
25	11.7	21.14	16.98
26	12.13	22.03	17.16
27	14.55	23.0	17.78
28	11.52	24.38	16.21

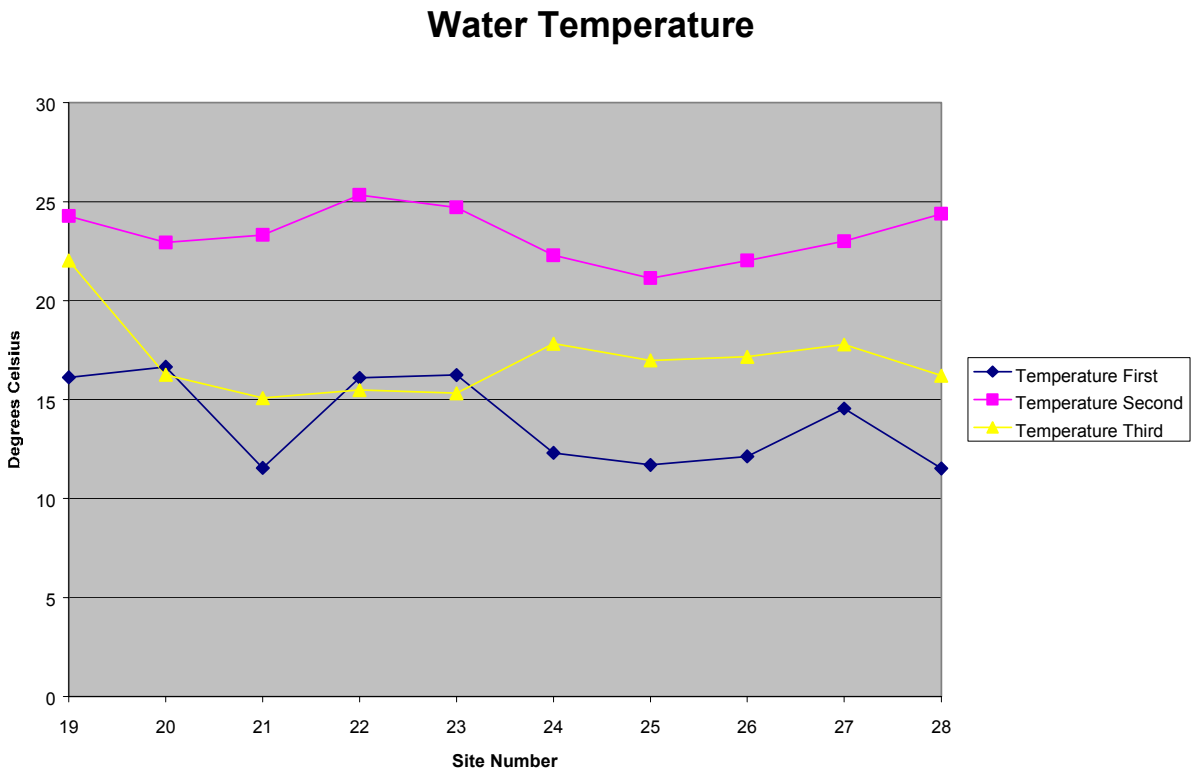

FIGURE 10

LAKE DISSOLVED OXYGEN MEASUREMENTS IN MG/L

Dissolved Oxygen			
Site #	First Sampling	Second Sampling	Third Sampling
19	7.80	7.76	5.55
20	8.75	2.31	5.81
21	9.92	3.08	7.28
22	8.26	7.66	7.94
23	9.50	4.03	7.7
24	9.78	6.1	6.9
25	5.92	2.16	7.01
26	8.16	6.96	6.57
27	6.30	4.24	7.65
28	5.90	7.27	5.55

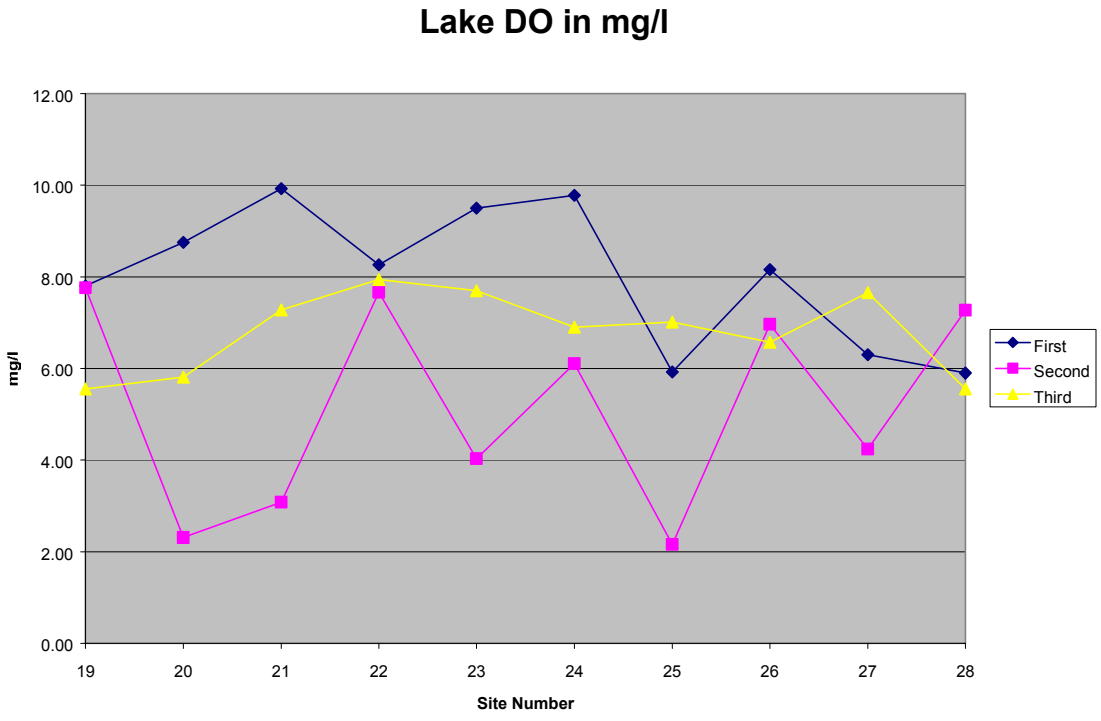

FIGURE 11

LAKE TURBIDITY IN NTUS

Turbidity (NTU)			
Site #	First Sampling	Second Sampling	Third Sampling
19	11.9	11.4	23.5
20	19.4	12	6.5
21	22.7	28.9	5.3
22	9.5	16.7	23.5
23	8.2	18.9	31.3
24	9.58	17	10.1
25	9.4	13.9	26.1
26	7.5	5.9	17.7
27	13.6	21	19.2
28	7.8	18	16.7

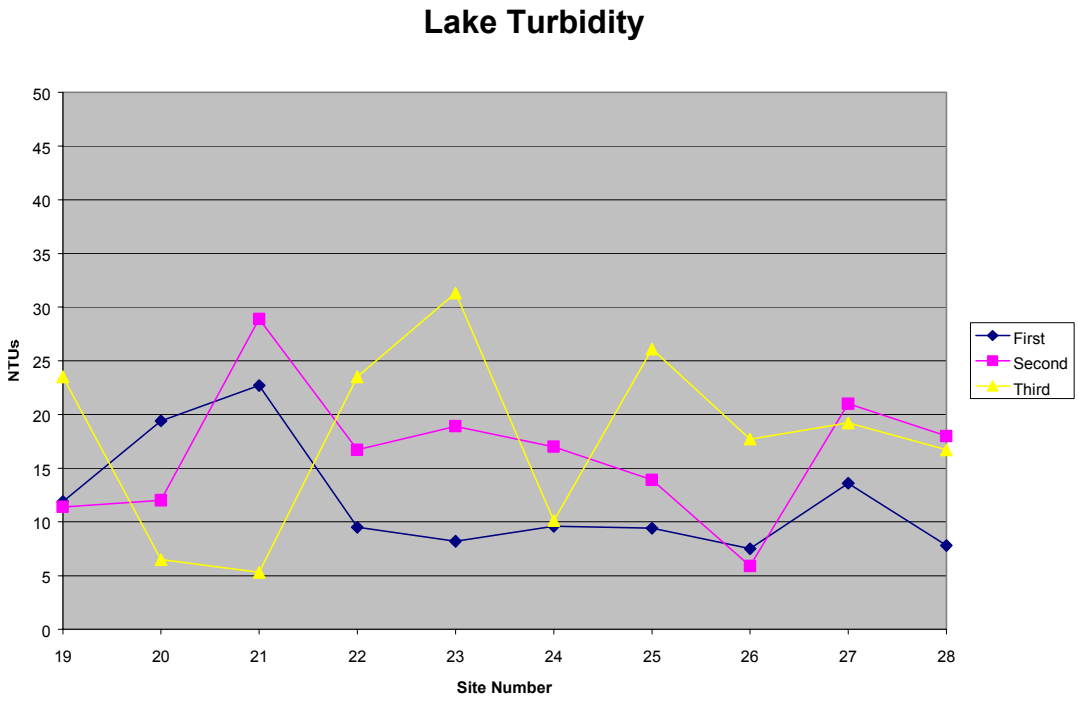

FIGURE 12

LAKE SPECIFIC CONDUCTIVITY IN µS/cm

Specific Conductivity (µS/cm)			
Site #	First Sampling	Second Sampling	Third Sampling
19	0.9311	0.9082	0.979
20	1.122	0.9832	0.9486
21	1.319	1.126	0.9534
22	1.846	1.505	1.566
23	1.843	1.509	1.561
24	2.058	1.639	1.665
25	3.219	2.584	2.609
26	6.222	4.97	4.953
27	10.97	8.729	8.86
28	11.2	8.782	8.693

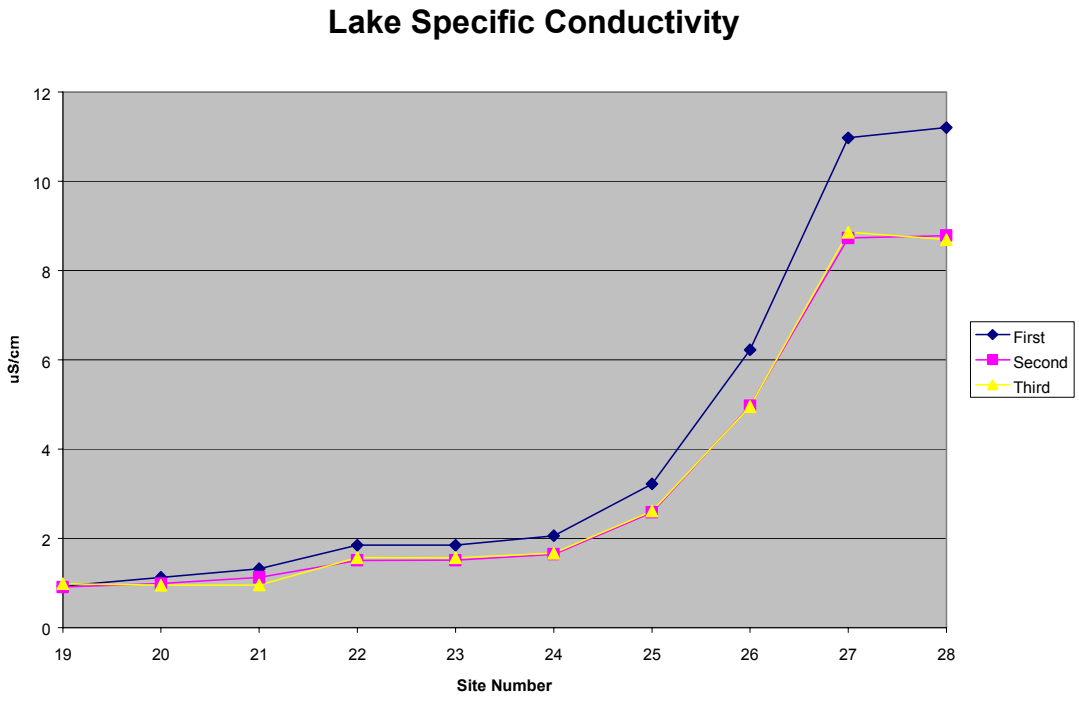

FIGURE 13

LAKE pH

pH			
Site #	First Sampling	Second Sampling	Third Sampling
19	8.64	8.84	8.51
20	8.89	8.46	8.56
21	8.7	8.19	8.79
22	8.71	8.91	8.81
23	8.77	8.7	8.82
24	8.73	8.78	8.73
25	8.76	8.58	8.9
26	8.87	8.88	8.91
27	8.79	8.71	8.77
28	8.84	8.83	8.81